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(81) 指定国 KR, US.

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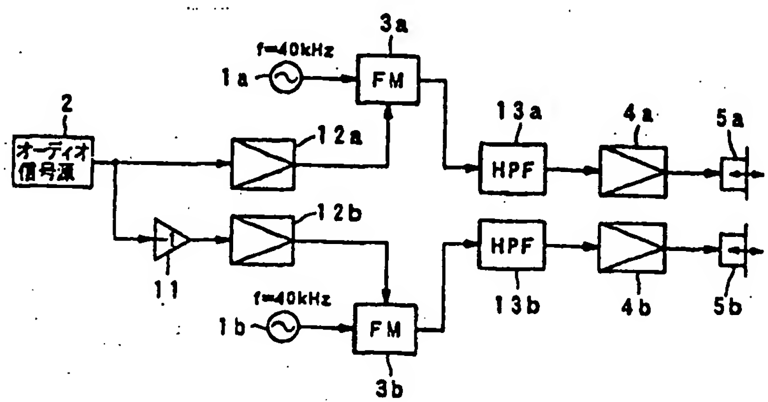
国際調査報告書

(54)Title: LOUDSPEAKER DEVICE AND METHOD FOR DRIVING THE SAME, AND AUDIO SIGNAL TRANSMITTER/RECEIVER

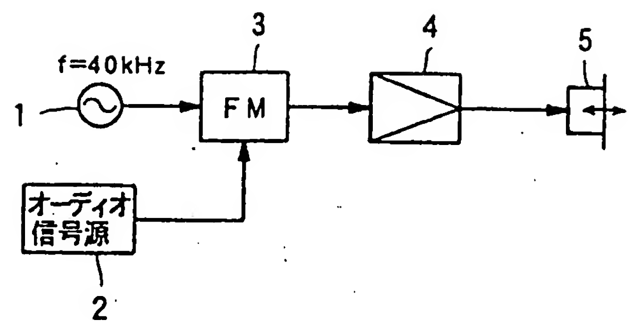
(54)発明の名称 スピーカ装置及びその駆動方法、オーディオ信号送受信装置



2 ... AUDIO SIGNAL SOURCE

(57) Abstract

An audio signal outputted from a sound source is modulated into a signal with a frequency in a frequency band higher than the audio frequency band by a modulator. An ultrasonic wave generating device is driven by the signal whose frequency is modulated by the modulator. The modulator modulates the audio signal outputted from the sound source into signal with a first frequency and signal with a second frequency which is different from the first frequency. By driving the ultrasonic wave generating device by thus modulated signals, a frequency component corresponding to the difference between the ultrasonic wave with the first frequency and the ultrasonic wave with the second frequency is heard as an audio sound. Since the ultrasonic wave is generated by the ultrasonic wave generating device, a super directivity can be realized.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FM
オーディオ
信号源
2

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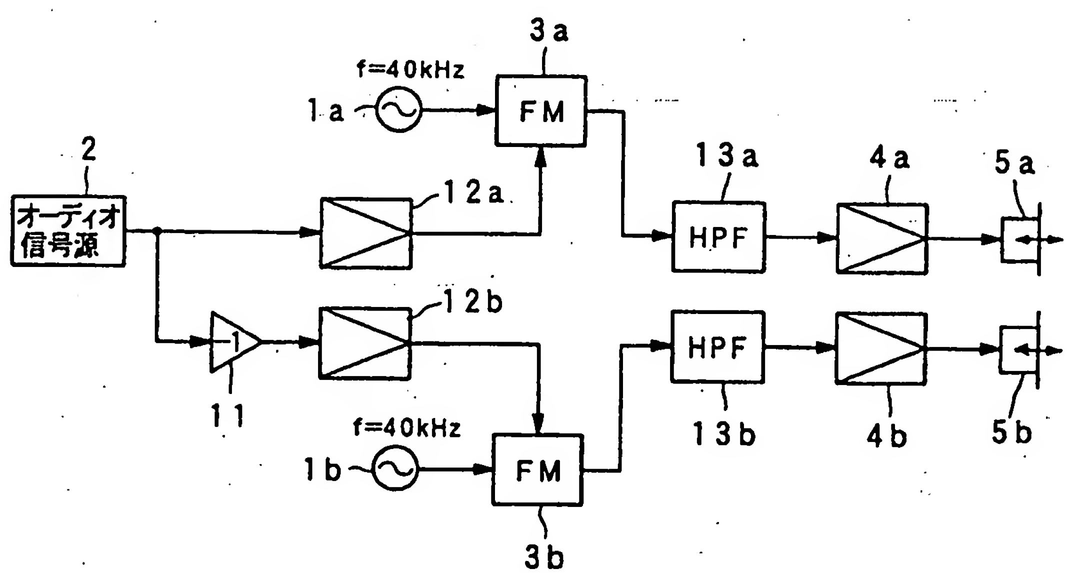
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3b

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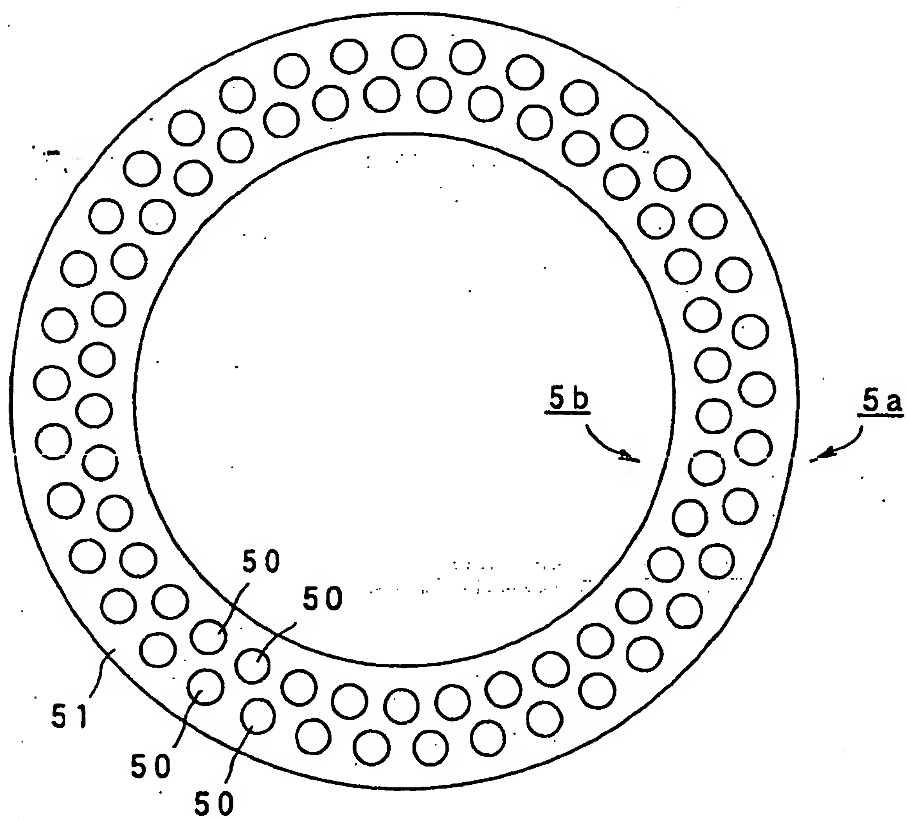

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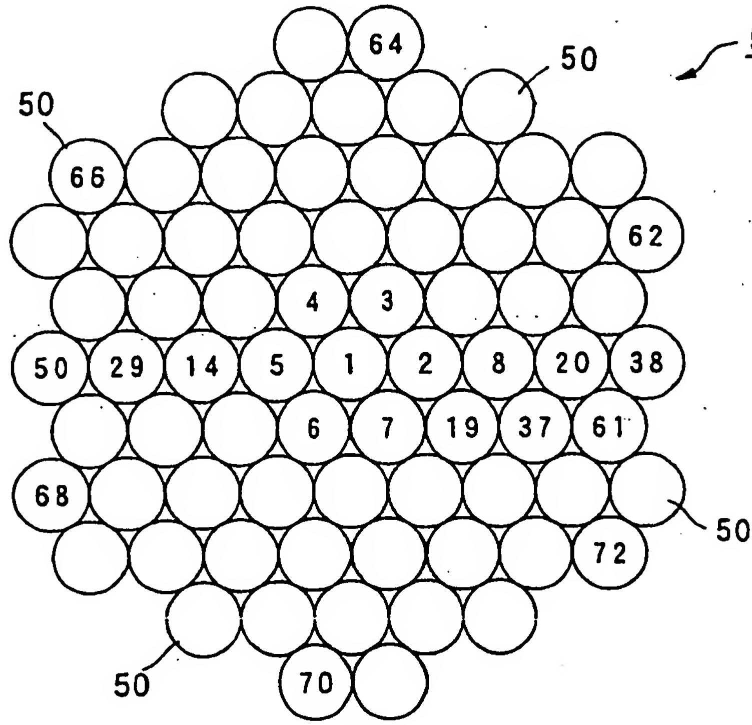
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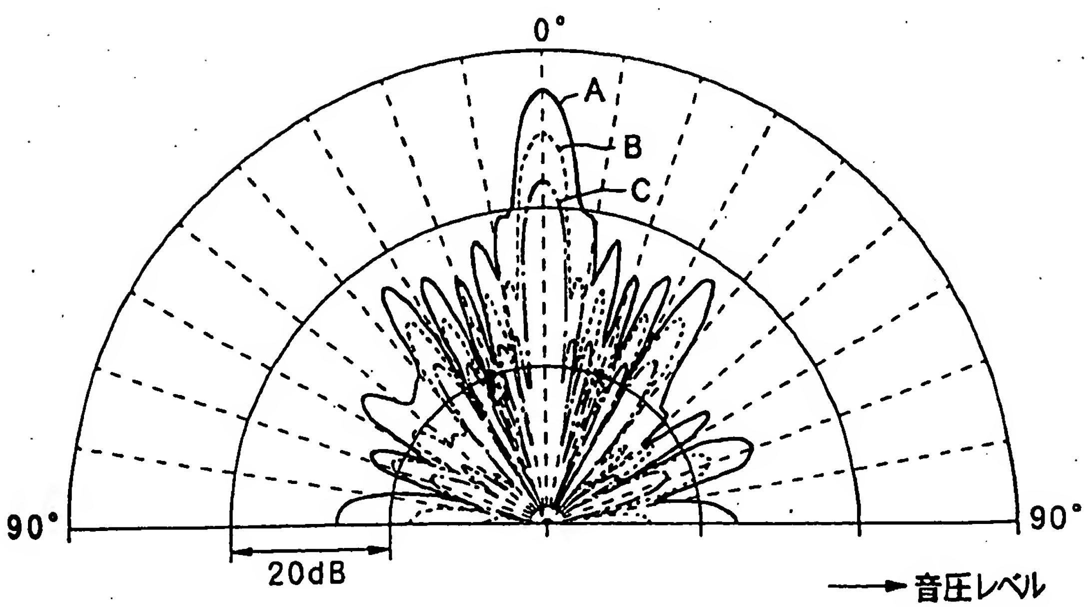
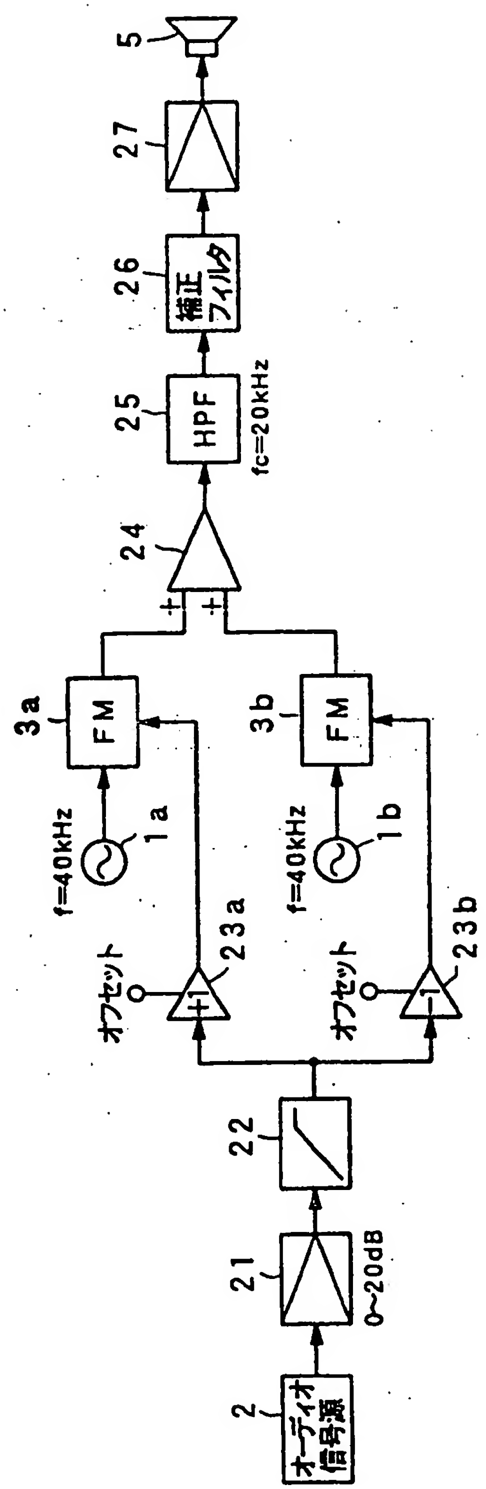

0°
A
B
C
90°
90°
20dB
音圧レベル

図 5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0~20dB
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23a
23b
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3b
FM
24
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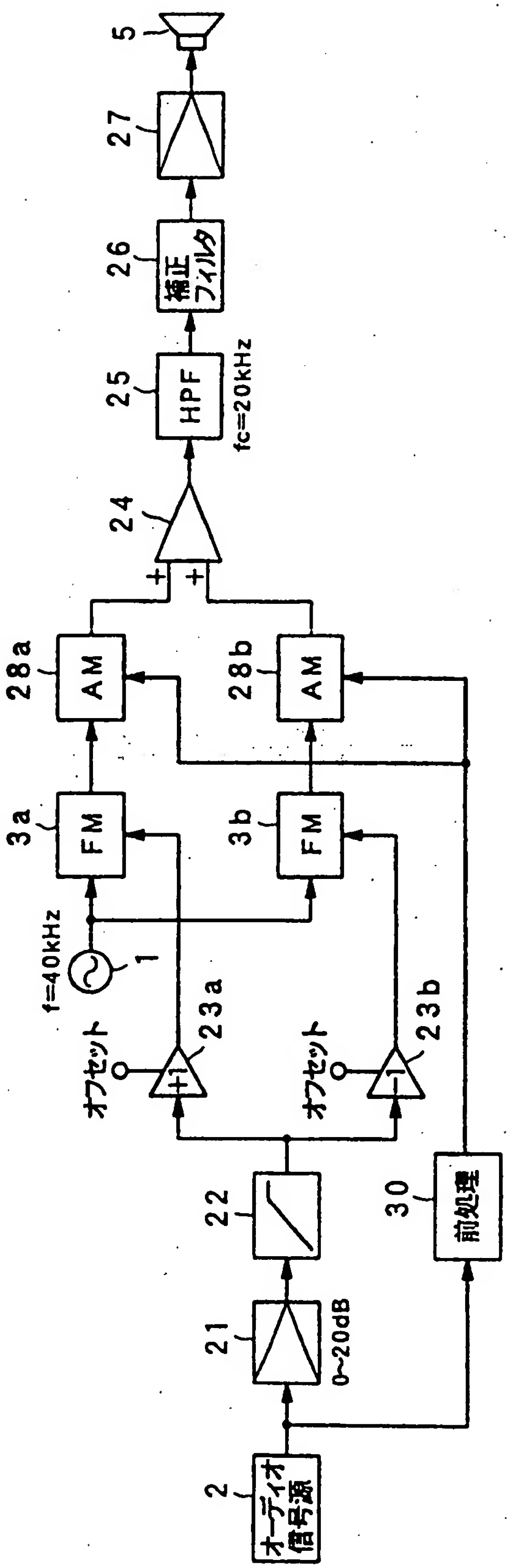
HPF
fc=20kHz
26
補正フィルタ
27
5

図 6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1
3a
FM
3b
FM
28a
AM
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AM
+
+
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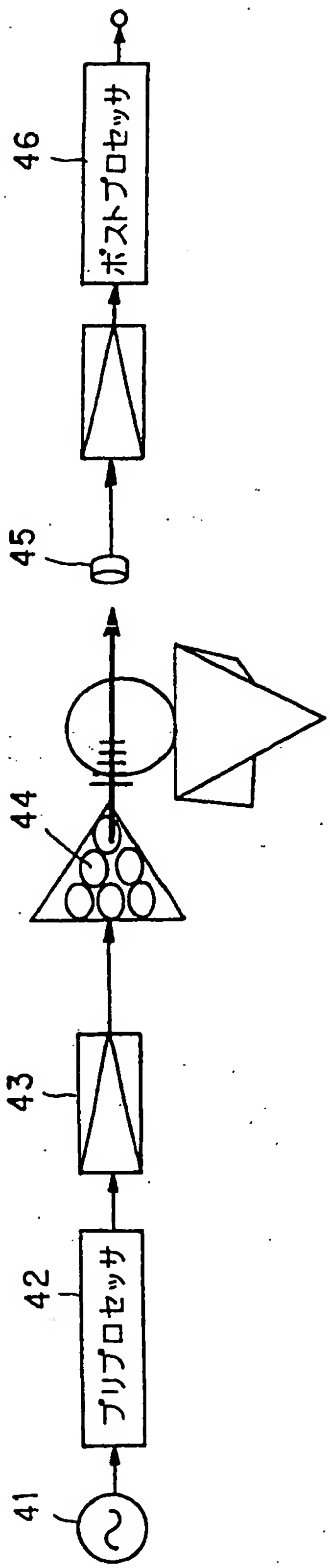
HPF
fc=20kHz
26
補正フィルタ
27
5

図 7



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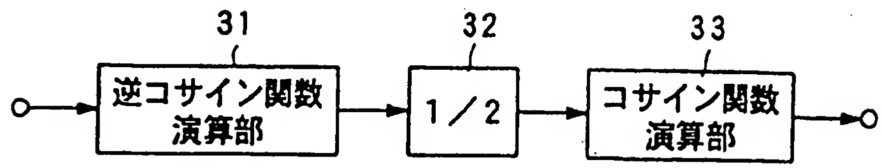

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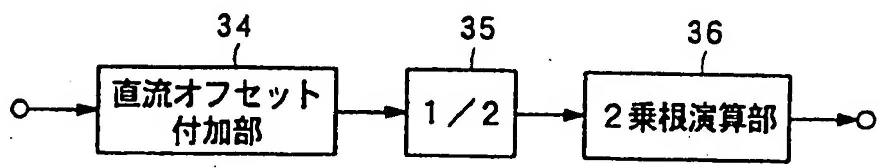

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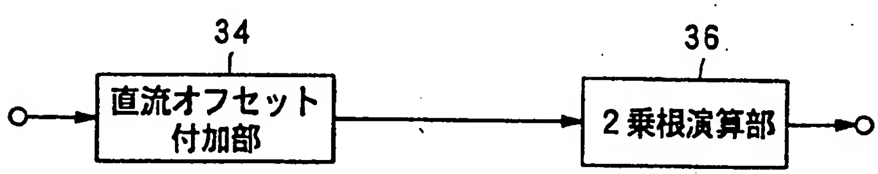

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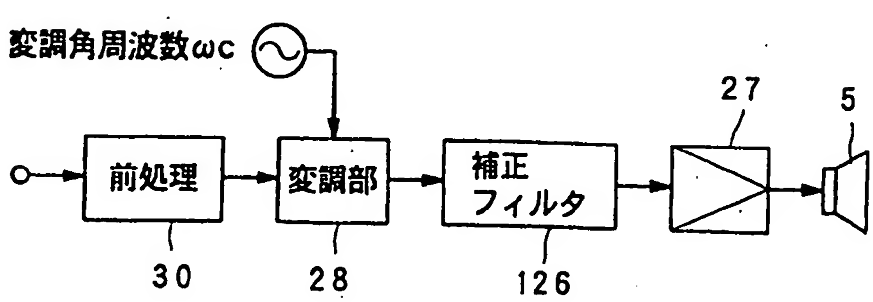

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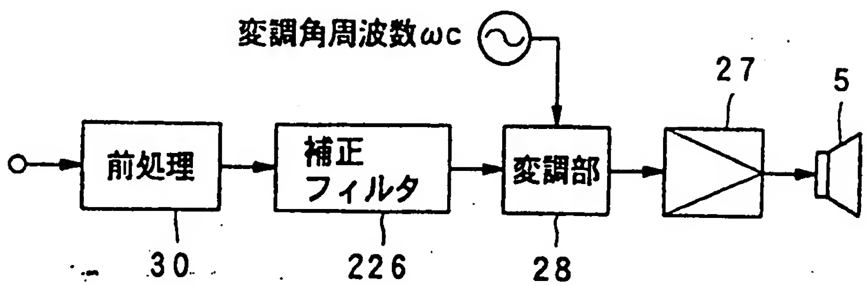
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前処理
補正
フィルタ
変調部
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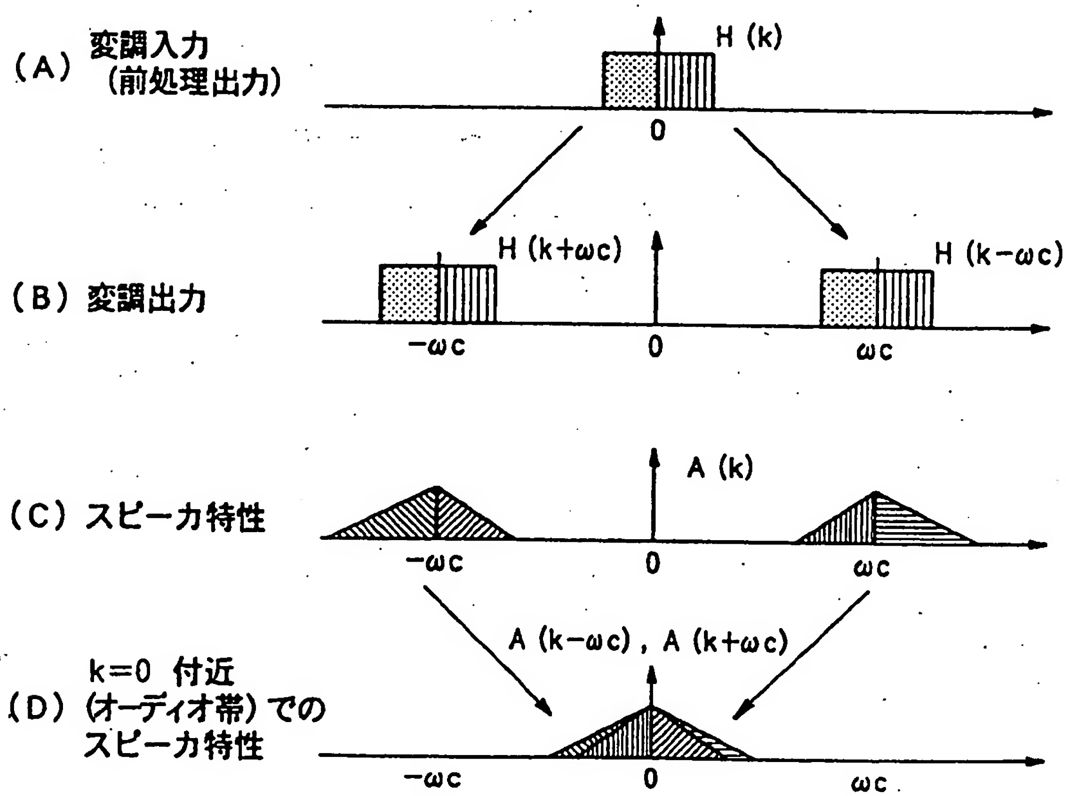
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(前処理出力)
H (k)
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(B) 変調出力
H (k+ωc)
H (k−ωc)
−ωc
0
ωc
(C) スピーカ特性
A (k)
−ωc
0
ωc
A (k−ωc), A (k+ωc)
k=0 付近
(D) (オーディオ帯) での
スピーカ特性
−ωc
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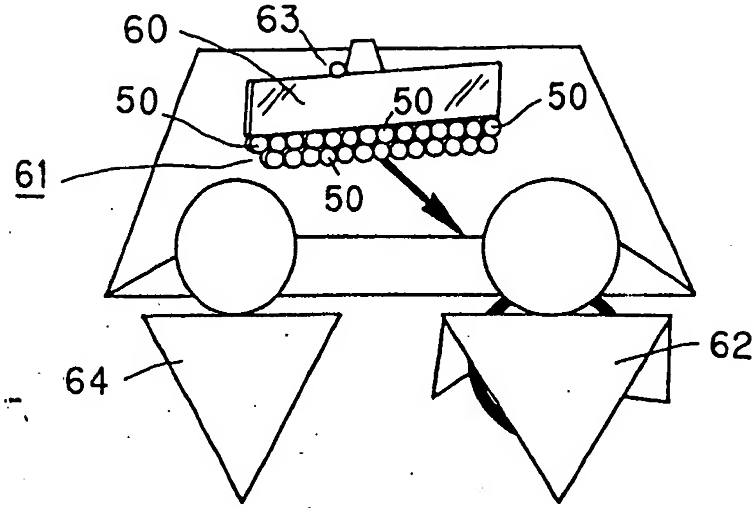
ωc

図14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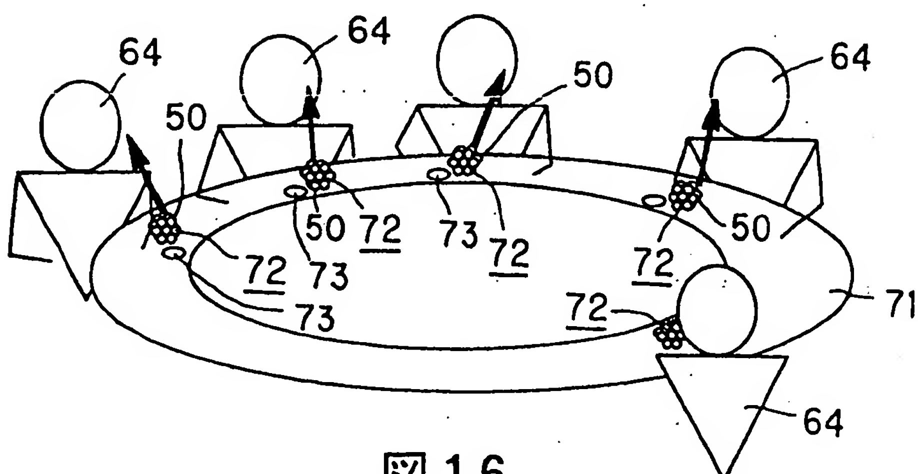
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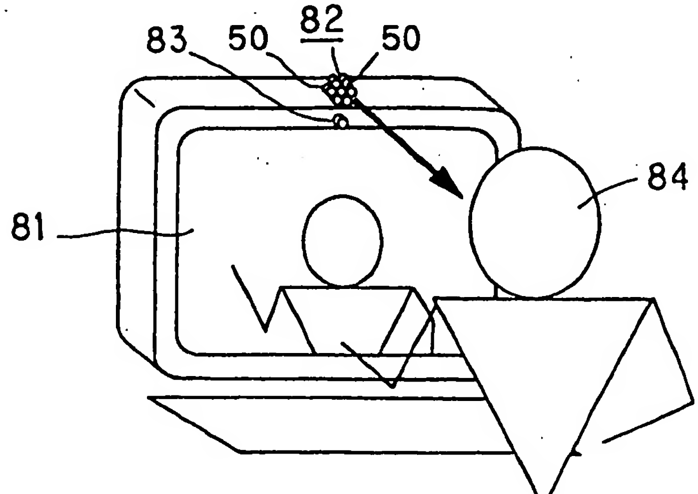
図16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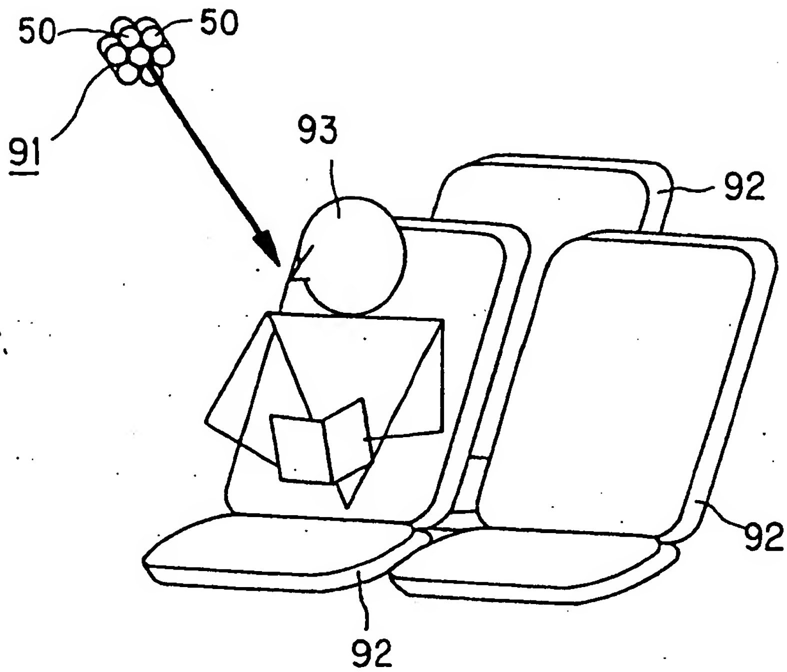
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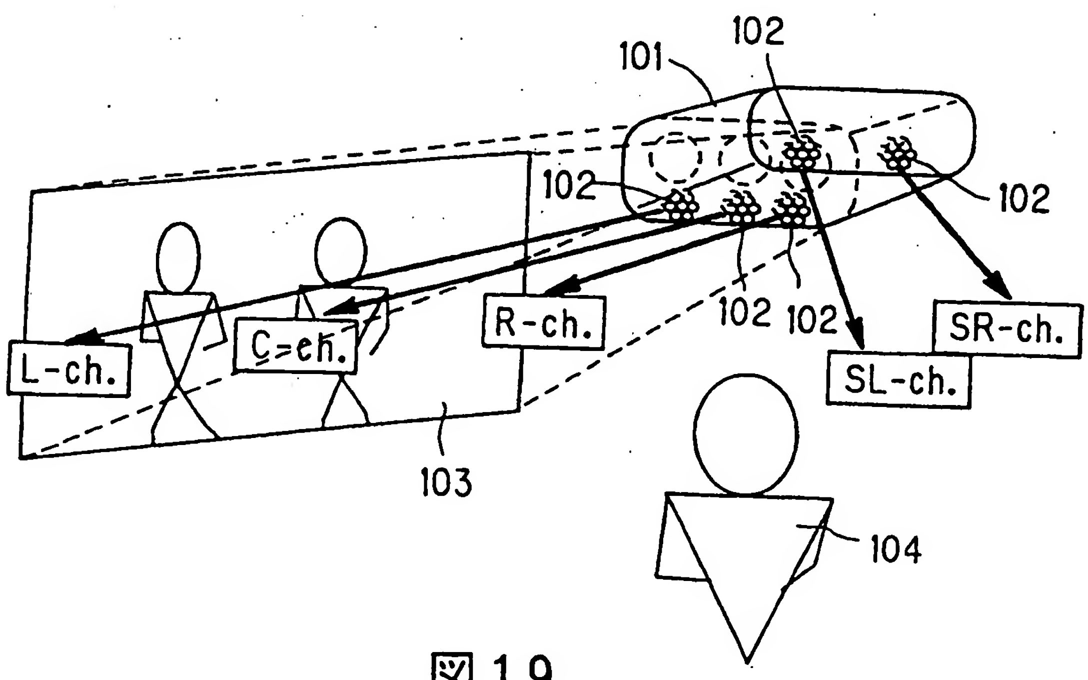
101
102
102
102
102
102
102
L-ch.
C-ch.
R-ch.
SL-ch.
SR-ch.
103
104

図19

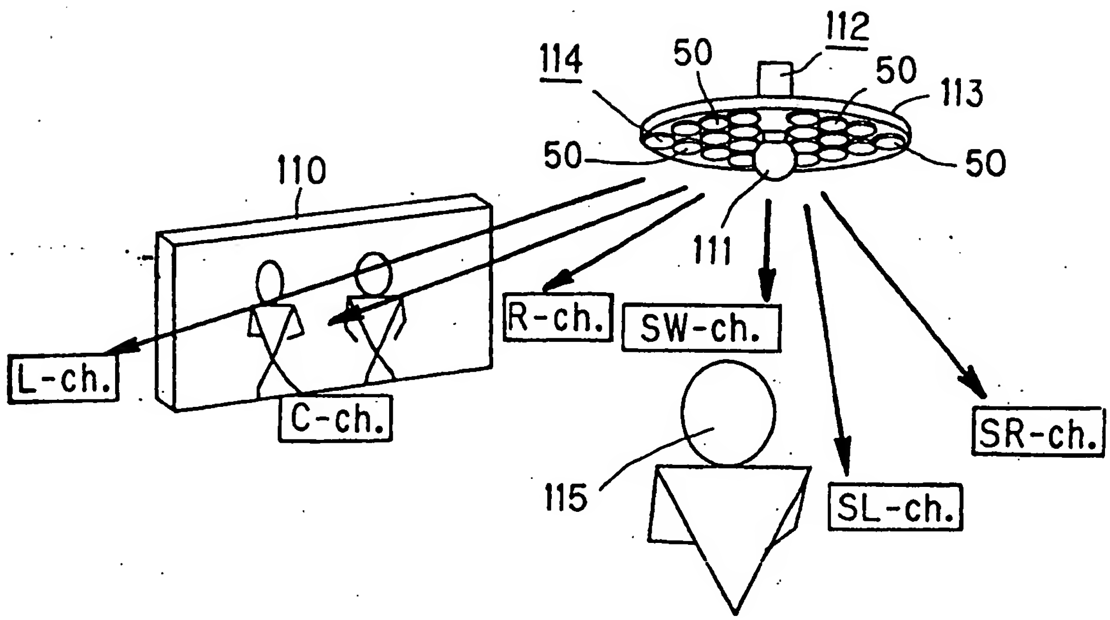
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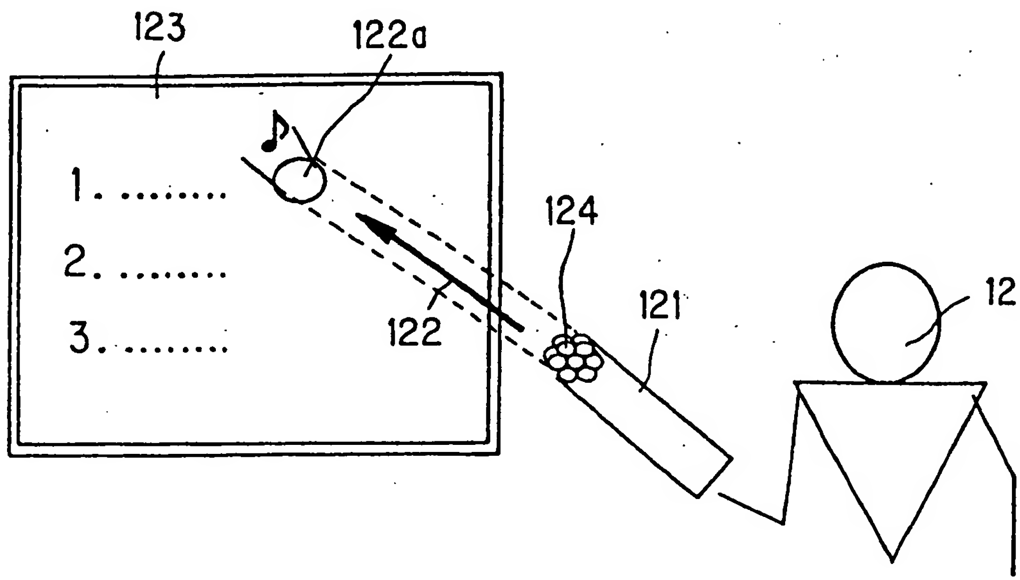
図20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3. ....
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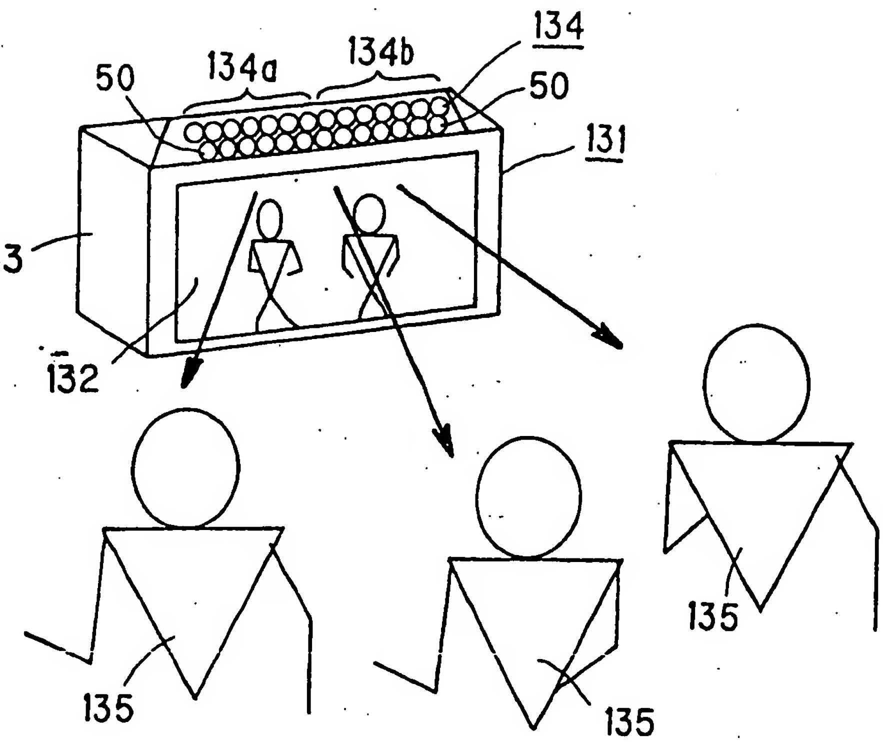
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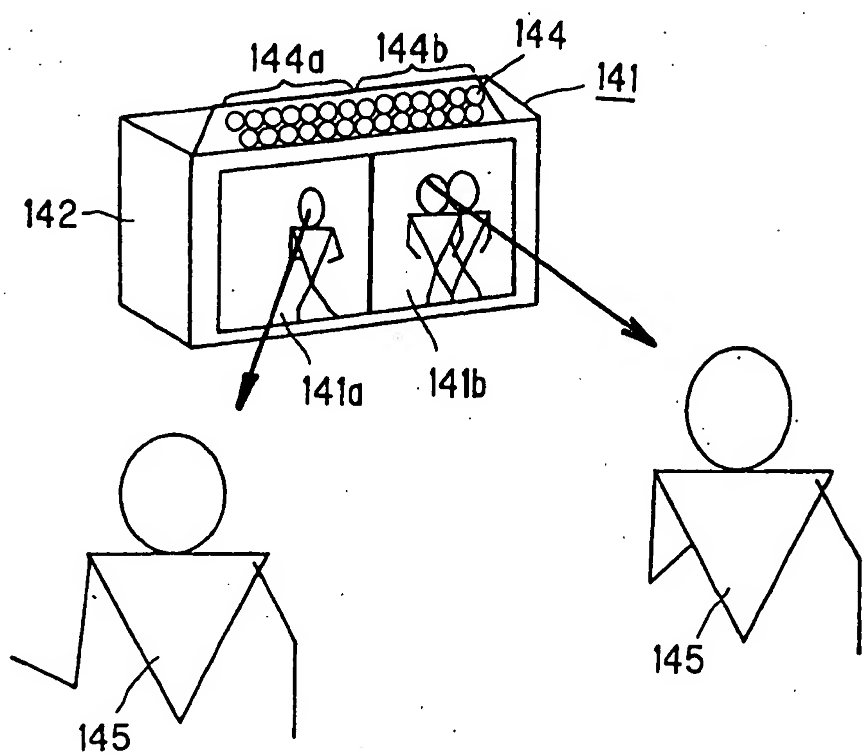
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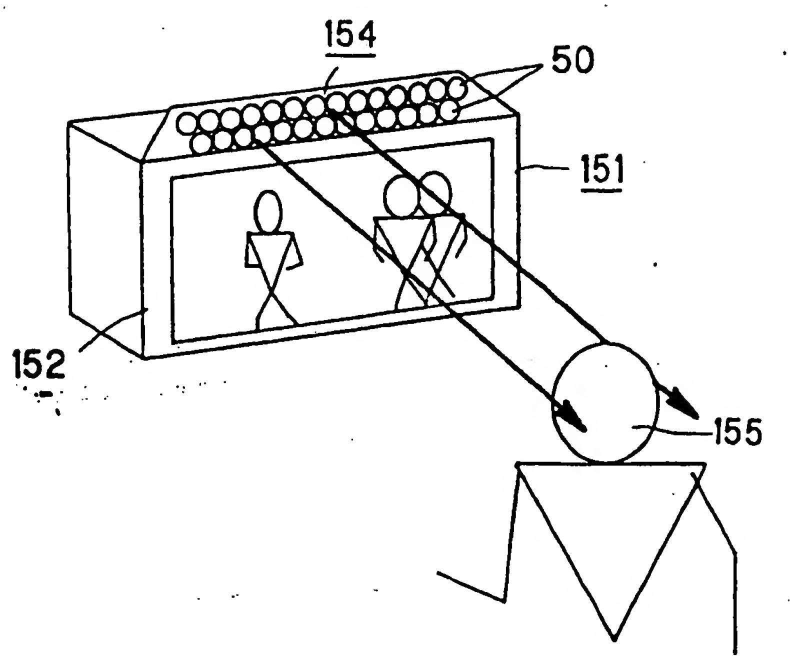
145

図23



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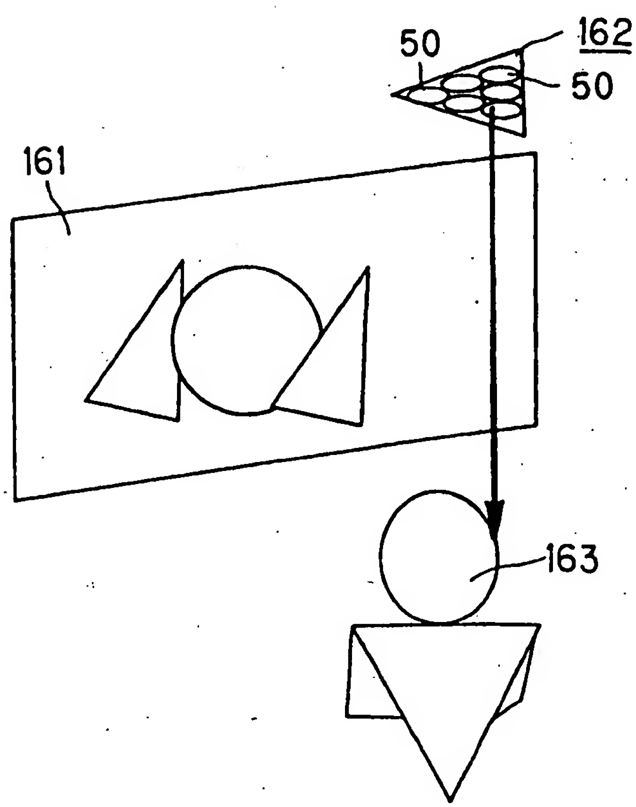

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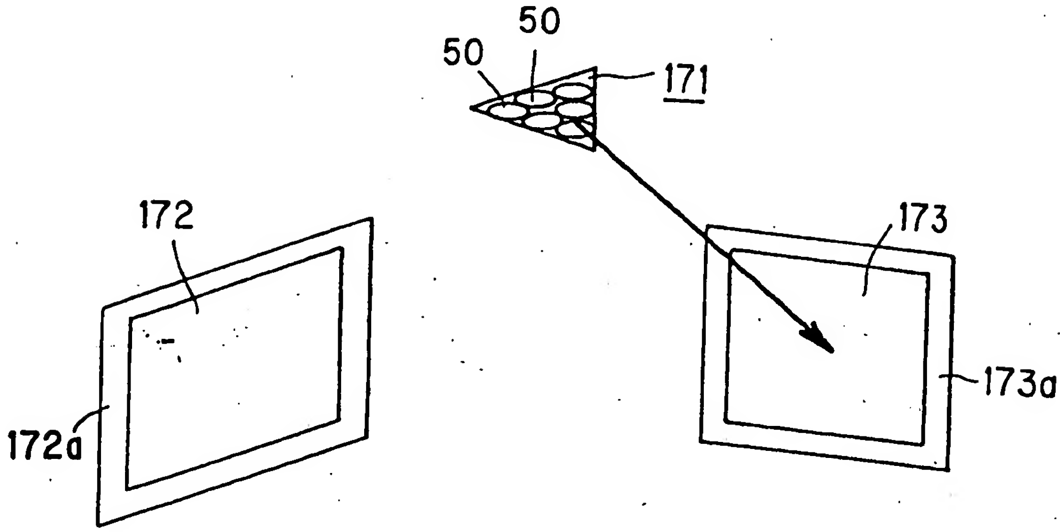

図２６

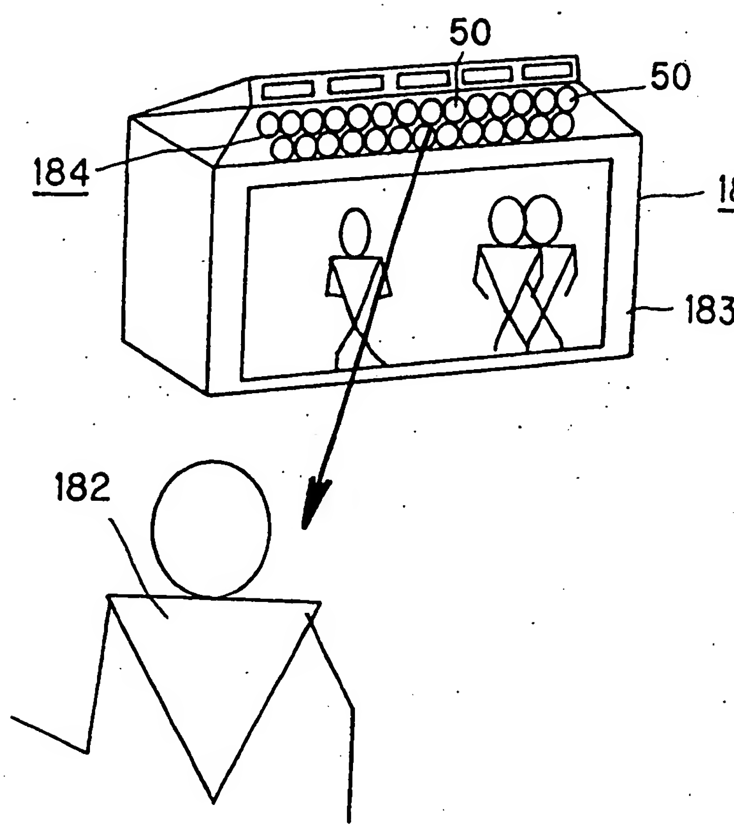

図２７

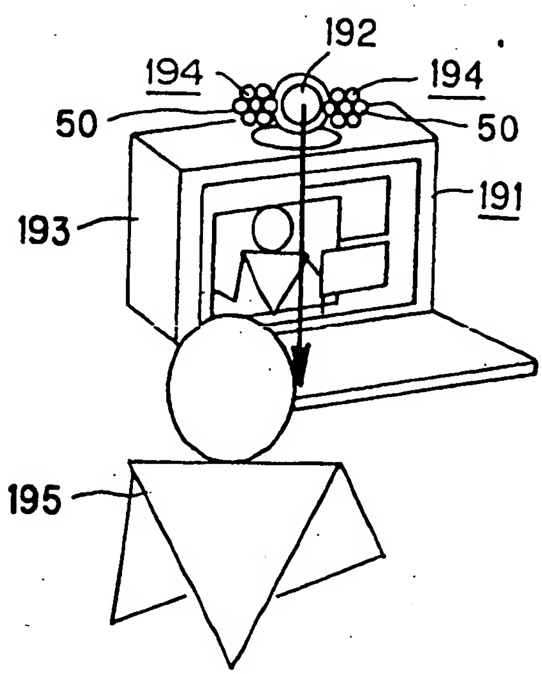

図28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/06008

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^6 H04R3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^6 H04R3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-1999
Kokai Jitsuyo Shinan Koho	1971-1999	Jitsuyo Shinan Toroku Koho	1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, 58-119293, A (Nippon Columbia Co., Ltd.), 15 July, 1983 (15. 07. 83) (Family: none)	1 6-37
X	JP, 2-253799, A (Matsushita Electric Works,Ltd.), 12 October, 1990 (12. 10. 90) (Family: none)	2
X Y	JP, 60-150399, A (Matsushita Electric Industrial Co., Ltd.), 8 August, 1985 (08. 08. 85) (Family: none)	3, 18 4
X	JP, 60-75199, A (Ricoh Co., Ltd.), 27 April, 1985 (27. 04. 85) (Family: none)	5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
2 March, 1999 (02. 03. 99)

Date of mailing of the international search report
16 March, 1999 (16. 03. 99)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

WORLD INTELLECTUAL PROPERTY ORGANIZATION
INTERNATIONAL OFFICE

INTERNATIONAL APPLICATION THAT WAS PUBLISHED BASED ON THE PATENT COOPERATION TREATIES

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(11) International publication number: **WO99/35881**

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(30) Priority right data: Patent application Hei 10/3483 January 9, 1998
Patent application Hei 10/340706 November 30,1998

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(81) Designated countries: KR, US

Published paper attachment
International research report

(54) Title: LOUDSPEAKER DEVICE AND METHOD FOR DRIVING THE SAME, AND AUDIO SIGNAL TRANSMITTER/RECEIVER

Figure

(57) Abstract *(as written in the application)*

An audio signal outputted from a sound source is modulated into a signal with a frequency in a frequency band higher than the audio frequency band by a modulator. An ultrasonic wave generating device is driven by the signal whose frequency is modulated by the modulator. The modulator modulates the audio signal outputted from the sound source into signal with a first frequency and signal with a second frequency which is different from the first frequency. By driving the ultrasonic wave generating device by thus modulated signals, a frequency component corresponding to the difference between the ultrasonic wave with the first frequency and the ultrasonic wave with the second frequency is heard as an audio sound. Since the ultrasonic wave is generated by the ultrasonic wave generating device, a super directivity can be realized.

(Reference) List of country codes

Details

Speaker devices and their drive methods and audio signal transmitter and receiver devices.

Technology Field

This invention is related to speaker devices, which reproduce audio signals using ultrasonic wave generating elements and their drive methods, as well as audio signal transmitter devices, which use ultrasonic wave generating elements.

Background Technology

Currently, most speaker devices that are used are designed to vibrate a vibrating plate, which broadcasts sound into the air. This type of speaker device vibrates the vibrating plate using audio signals across the audible frequency range of 20 Hz to 20 kHz, and sound waves are broadcast from the vibrating plate directly to the air.

However, speakers that have their vibrating plates driven by audio signals in the audible range, primarily use the vibrating plate to broadcast sound across a broad airspace. This type of speaker device is useful when sound must be broadcast over a large area.

However, this type of speaker device cannot point its sound to a specific listener.

Also, in order for only one individual listener to listen, earphones or headphones are used on the head or ears. This type of headphone or earphone also has the vibrating plate driven by audio signals across the audible range, and primarily uses the vibrating plate to broadcast sound across an airspace. With headphones or earphones, in order to maintain privacy, the speaker unit is enclosed, and must be attached to the head or ears.

Disclosure of Invention

The purpose of this invention is to provide a speaker device and its corresponding drive method that can broadcast sound in a very detailed direction using a new drive method.

Another purpose of this invention is to provide a speaker device and its corresponding drive method that can broadcast sound while maintaining privacy.

Yet another purpose of this invention is to provide a speaker device and its corresponding drive method that can simultaneously provide different sounds to listeners in different locations.

Yet another purpose of this invention is to provide a speaker device and its corresponding drive method that can freely establish an orientation of the sound in any position.

Yet another purpose of this invention is to provide an audio signal transmitter/receiver device that can receive and transmit audio signals with an improved privacy function.

In order to accomplish these purposes, the speaker device used in this invention has a modulator to modulate the frequency to a signal with a frequency range at least higher than the audible frequency range, and at least one ultrasonic wave generating element that is driven by the output signal of the modulator.

The modulator modulates the audio signal to a number 1 frequency modulated signal based upon a number one frequency, and also modulates the same signal to a number 2 frequency modulated signal based on the number 2 frequency which is different than the number 1 frequency.

Also, the speaker devices associated with this invention are prepared with multiple ultrasonic wave generating elements, and a part of these multiple ultrasonic wave generating elements are fed with the number 1 signal, and the rest of the elements are fed with the number 2 signal.

Also, the speaker devices associated with this invention are prepared with a splitter to divide the signal. Here, the modulator is prepared with a part 1 and a part 2, and one of these two parts of the modulator receives the output signal from the splitter, while the other part of the modulator receives the reversed polarity of the output signal.

Also, the speaker devices associated with this invention are prepared with a circuit number 1 which delivers from the splitter to either the number 1 or number 2 modulator part, a signal which has the direct current level shifted from the output signal, and a circuit number 2 which delivers from the splitter to the other modulator part a signal which has the reversed polarity as well as the direct current level shifted from the output signal.

Also, the speaker devices associated with this invention are designed with a preprocessing circuit that further prepares the audio signal. Here, the modulator is designed with a number 1 amplitude modulator that uses the output signal from the number 1 modulator part as carrier waves to modulate the amplitude of the output signal from the preprocessing circuit, and a number 2 amplitude modulator that uses the output signal from the number 2 modulator part as carrier waves to modulate the amplitude of the output signal from preprocessing circuit.

The speaker devices associated with this invention are also designed with a compensating filter placed between the modulator and the ultrasonic wave generating elements. This compensating filter regulates the portion of the output signal from the modulator that has a sympathetic vibration frequency with the ultrasonic wave generating elements.

Also, the speaker devices associated with this invention are designed with a modulator, having a

number 1 modulator part and a number 2 modulator part where one of the two parts is fed the audio signal while the other part is fed a signal with reverse polarity from the audio signal, which modulates the frequency of the audio signal to a frequency at least higher than the audible frequency range. The speaker devices are also designed with ultrasonic wave generating elements that are driven by the output signal from the above modulator. The ultrasonic wave generator has a part 1 which consists of the multiple ultrasonic wave generating elements which are driven based on the output signal from the number 1 modulator part and a part 2 which consists of the multiple ultrasonic wave generating elements which are driven based on the output signal from the number 2 modulator part.

Also, the audio signal transmitter/receiver device of this invention is designed with a modulator that modulates the frequency of the carrier waves using the signal that split the audio signal, an ultrasonic wave generator that is driven based on the output signal from that modulator, a microphone that detects the sound waves that are output from the ultrasonic wave generator, and an operator which performs an inverse cosine function on the output signal from the microphone.

The microphone contained in the audio signal transmitter/receiver device detects the sound waves in the audible frequency range output from the ultrasonic wave generator.

Also, the drive method of the speaker devices of this invention which contain ultrasonic wave generating elements, consists of modulating the frequency of the input audio signal to a frequency range at least higher than the audible frequency range, and then driving the ultrasonic wave generating elements using the frequency modulated signal.

For this drive method, the audio signal is modulated to a number 1 frequency modulated signal based on the number 1 frequency, and a number 2 frequency modulated signal based on the number 2 frequency.

Other purposes and other material benefits of this invention will probably be made clear in the explanation of the actual examples shown below.

Simple Explanation of Figures

Figure 1 is a circuit diagram showing the basic structure of the speaker devices of this invention.

Figure 2 is a circuit diagram of the speaker devices of this invention.

Figure 3 is a flat drawing that shows one row of the arrangement of ultrasonic wave generators which are associated with the speaker devices of this invention.

Figure 4 is a flat drawing that shows the other rows of the arrangement of ultrasonic wave generators that are associated with the speaker devices of this invention.

Figure 5 is a characteristics drawing that shows the directivity of the speaker devices of Figure 4.

Figure 6 is a circuit drawing showing another arrangement of the speaker devices of this invention.

Figure 7 is a circuit diagram that shows yet another arrangement of the speaker devices of this invention.

Figure 8 is a circuit diagram showing an audio signal transmitter device associated with the speaker devices of this invention.

Figure 9 is a block diagram that shows the DSP functions that make up the preprocessing circuit.

Figure 10 is a block diagram that shows the DSP functions that make up the preprocessing circuit.

Figure 11 is a block diagram that shows the DSP functions that make up the preprocessing circuit.

Figure 12 is a block diagram that shows the circuit structure of a speaker device equipped with a compensating filter.

Figure 13 is a block diagram that shows the circuit structure of a speaker device equipped with a compensating filter.

Figure 14 is a sketch to show the compensating principles of the speaker characteristics in the audio range.

Figure 15 is an angle view sketch showing an example of the speaker devices of this invention attached to an automobile interior rear view mirror for a hands free type vocal input communicator device.

Figure 16 is an angle view of showing an example of a conference system using the speaker devices of this invention.

Figure 17 is an angle view sketch showing an example of the speaker devices of this invention used in a video telephone device.

Figure 18 is an angle view sketch showing an example of the speaker devices of this invention used in a sound system that is installed in a vehicle.

Figure 19 is an angle view sketch showing an example of the speaker devices of this invention used in projection type video projector.

Figure 20 is an angle view sketch showing an example of the speaker devices of this invention used in a audio visual device.

Figure 21 is an angle view sketch showing an example of the speaker devices of this invention used in an overhead projector pointer device.

Figure 22 is a angle view sketch showing an example of the speaker devices of this invention used in a player device that reproduces information in various languages that are recorded on an information recording medium.

Figure 23 is an angle view sketch showing an example of the speaker devices of this invention used in a double screen television receiver.

Figure 24 is an angle view sketch showing an example of the speaker devices of this invention used in a television receiver.

Figure 25 is an angle view sketch showing an example of the speaker devices of this invention used in an art or science museum exhibit room.

Figure 26 is an angle view sketch showing an example of the speaker devices of this invention in other configurations.

Figure 27 is an angle view sketch showing an example of the speaker devices of this invention used in a television receiver that allows for a homing function.

Figure 28 is an angle view sketch showing an example of the speaker devices of this invention used in other examples of a television receiver that allows for a homing function.

Optimal Format for This Invention

The speaker device of this invention, the drive method of the speaker device, as well as the audio signal transmitter device that uses this speaker device will be explained below.

The basic structure of the speaker device of this invention will be explained using Figure 1 as a reference.

As shown in Figure 1, the speaker device consists of a carrier wave oscillator 1 that has as a fixed frequency carrier wave output, an audio signal source 2 that outputs the audio signal, a frequency modulator 3 that modulates the frequency of the carrier waves from the carrier wave oscillator 1, using the audio signal from the audio signal source 2, and an ultrasonic wave generator 5 that is driven by the carrier waves (hereafter referred to as frequency modulated signal) that was frequency modulated and output by the frequency modulator 3.

The carrier wave oscillator 1 provides fixed frequency carrier waves, for instance 40 kHz, to the frequency modulator 3. The audio signal source 2 provides an audio signal from, for instance, a laser disc player or a tape recorder, etc., to the frequency modulator 3. The frequency modulator 3 frequency modulates the carrier waves that were input from the carrier wave generator 1, using the modulated frequency from the audio signal source 2. This frequency modulated signal is passed through an amplifier 4, and then input into the ultrasonic wave generator 5. The ultrasonic wave generator 5, which is composed of at least one ultrasonic wave generating element, has an extremely high directivity characteristic (Hereafter referred to as high directivity), and is driven by the amplified frequency modulated signal from the amplifier 4 so that it broadcasts, in the direction the ultrasonic wave generator 5 is pointed, ultrasonic waves based on the frequency modulated signal, with high directivity. When the ultrasonic wave generator 5 is positioned towards the user, a sound corresponding to the audio signal from the

audio signal source 2 can be heard. Also, for instance when the ultrasonic wave generator 5 is pointed at a wall, the user feels as if the sound is coming from the wall.

Now, the basic principle of why when the ultrasonic waves based on the frequency modulated signal that was frequency modulated using the audio signal from the audio signal source 2 are broadcast, a sound that corresponds to the original audio signal is heard, will be briefly explained.

As shown in Equation 1, there is a family of non-linear equations with even degrees, and when a signal containing 2 frequency components ($w_1 / 2\pi$, $w_2 / 2\pi$) as shown in Equation 2 is input, a differential frequency distortion is created, which is a type of hybrid modulated distortion as shown in Equation 3.

Equation 1

Where x is the family of input signals and y is the family of output signals.

Equation 2

When Equation 2 is input to Equation 1, the following Equation 3 is derived.

Equation 3

Where Item 1 is the basic wave component, Item 2 is the direct current component, Item 3 is the Number 2 high pitch wave component, Item 4 is the differential frequency component, and Item 5 is the harmonic frequency component. The differential frequency component of Item 4 is the differential frequency distortion, and it appears in the family of outputs as the frequency component (differential sound) that corresponds to difference of the frequencies ($w_1 - w_2$). For instance, if sine wave signals at 40 kHz and 41 kHz output from two carrier wave generators are mixed and used to drive the ultrasonic wave generator, a differential sound corresponding to 1 kHz differential frequency distortion can be heard.

However, as is widely known, in frequency modulation, the frequency modulated signal contains countless lateral band waves that are centered on the carrier waves. It follows that if air, when subject to ultrasonic waves, exhibits characteristics of a non-linear equation with even degrees as shown above, then the original audio signal will be reproduced, and the user can hear sounds that correspond to it.

Next, the specific structure of the speaker devices of this invention that contain the basic components mentioned above will be explained using Figure 2 as a reference.

Circuits that have the same functions as the circuit used in the speaker devices of Figure 1, have

the same code attached, and the detailed explanation will be abbreviated.

As shown in Figure 2, this speaker device contains a number 1 and a number 2 carrier wave oscillator that each output fixed frequency carrier waves 1a, 1b, an audio signal source 2 that outputs the audio signal, a number 1 and number 2 frequency modulator 3a, 3b, that frequency modulate the carrier waves from both number 1 and number 2 carrier wave oscillators 1a, 1b, using the audio signal from the sound source 1 and the inverted audio signal, and a number 1 and number 2 ultrasonic wave generator 5a, 5b, that are driven by the frequency modulated signal output from the number 1 and number 2 frequency modulators 3a, 3b.

The number 1 and number 2 carrier wave oscillators 1a, 1b, each provide carrier waves of, for instance, 40 kHz to the number 1 and number 2 frequency modulators 3a, 3b. The audio signal source 2 provides to the frequency modulator 3a via the number one amplifier 12a, an audio signal that acts as the modulating signal, as well as providing the signal for the inverted circuit 11. The inverted circuit 11 inverts the amplitude of the audio signal received from the audio signal source 2, and feeds it to the number 2 frequency modulator 3b via the number 2 amplifier 12b. The number 1 and number 2 frequency modulators 3a, 3b frequency modulate the carrier waves input from the number 1 and number 2 carrier wave oscillators 1a, 1b, using the modulated signal that was amplified by the number 1 and number 2 amplifiers 3a, 3b. [The translator believes that this should read 12a, 12b] The produced frequency modulated signal is then passed through a number 1 and number 2 high pass filter 13a, 13b with a cutoff of, for instance, 20 kHz, where the components under 20 kHz are discarded. The signals are then passed through a number 1 and number 2 amplifier 4a, 4b, and then input to the number 1 and number 2 ultrasonic wave generators 5a, 5b. The number 1 and number 2 ultrasonic wave generators 5a, 5b contain at least one ultrasonic wave generating element, and are driven by the frequency modulated signal that was amplified by the number 1 and number 2 amplifiers 4a, 4b, which causes them to broadcast in the direction that the number 1 and number 2 ultrasonic wave generators 5a, 5b are pointed ultrasonic waves with directivity characteristics based on the frequency modulated signal.

Now the specific structure of the number 1 and number 2 ultrasonic wave generators 5a, 5b will be explained.

The number 1 and number 2 ultrasonic wave generators 5a, 5b are each built with multiple, for instance 37, individual ultrasonic wave generating elements or piezoelectric elements 50, and as shown in Figure 3 for example, the piezoelectric elements 50 of the number 1 ultrasonic wave generator 5a are arranged in a ring on the inside perimeter on top of a supporting substrate 51, and then surrounding the piezoelectric elements 50 of the number 1 ultrasonic wave generator 5a are arranged in a ring the piezoelectric elements 50 of the number 2 ultrasonic wave generator 5b. At this time, both the group of piezoelectric elements 50 of the number 1 ultrasonic wave generator 5a, and the piezoelectric elements

50 of the number 2 ultrasonic wave generator 5b are arranged in rings around the same axis.

When structured like this, and the number 1 and number 2 ultrasonic wave generators 5a, 5b possessing high directivity are pointed in the direction of the user, a sound can be heard that corresponds to the audio signal from the audio signal source 2. However, because these speaker devices broadcast differential ultrasonic waves from a number 1 and a number 2 ultrasonic wave generator 5a, 5b that are driven by the two frequency modulated signals that were frequency modulated using the audio signal and the inverted polarity audio signal, the user can hear a louder sound that when using the speakers shown in Figure 1. Also, by using more piezoelectric elements 50, the sound volume level can be increased.

In the above example, the speaker devices used two separate groups of piezoelectric elements 50, but it is also acceptable to mix the frequency modulated signals using a mixer, and then drive the one group of piezoelectric elements 50 using the mixed signal.

In this case, a group of, for instance 73 piezoelectric elements 50 are arranged in a cylinder shape in close proximity as shown in Figure 4. When speaker devices using ultrasonic wave generators 5 are built with tightly arranged multiple piezoelectric elements 50, an example of the directivity characteristics at a point 0.5 m away is shown by the characteristics of Point A in Figure 5, the directivity characteristics at a point 1 m away is shown by the characteristics of Point B in Figure 5, and the directivity characteristics at a point 2 m away is shown by the characteristics of Point C in Figure 5, showing that the speaker device has extremely high directivity in the direction it is facing.

The ultrasonic wave generator 5 shown in Figure 4, has multiple ultrasonic wave generator elements (piezoelectric elements 50) combined into various groups, and each group may be driven by inputting a frequency modulated signal. In this case, by combining the multiple ultrasonic wave generating elements into 2 groups, they can be used as the ultrasonic wave generators 5a 5b for the speaker devices shown in the previously mentioned Figure 2.

Next, using Figure 6 as a reference, other specific examples of the speaker devices of this invention will be explained. Circuits that have the same function as the circuits in the speaker devices shown in the previously mentioned Figure 2 have the same code attached, and their detailed explanation will be abbreviated.

As shown in Figure 6 the speaker devices contain the following items:

- a number 1 and number 2 carrier wave generator 1a, 1b that each output fixed frequency carrier waves;
- an audio signal source 2 that outputs the audio signal;
- a splitter 22 that splits the audio signal that is output from the audio signal source 2;
- an amplifier 23a that increases the offset voltage of the split signal that is output from the splitter 22;

- an inverse amplifier 23b that inverts the polarity of the split signal output from the splitter 22, and increases the offset voltage;
- a number 1 and number 2 frequency modulator 3a, 3b that frequency modulate the carrier waves from the number 1 and number 2 carrier wave generators 1a, 1b using the split signal from amplifier 23a and the split signal from the inverse amplifier 23b;
- a mixer 24 that mixes the frequency modulated signals from the number 1 and number 2 frequency modulators 3a, 3b;
- a compensating filter 26 that regulates a designated frequency component of the mixed frequency modulated signal from the mixer 24;
- and an ultrasonic wave generator 5 that is driven by the frequency modulated signal output from the compensating filter 26.

The number 1 and number 2 carrier wave generators 1a, 1b each supply carrier waves of, for instance, 40 kHz to the number 1 and number 2 frequency modulators 3a, 3b. The audio signal source 2 supplies the audio signal to the splitter 22 via the amplifier 21. The splitter 22 splits the audio signal amplified by the amplifier 21, and supplies the split signal to amplifier 23a and inverse amplifier 23b. The amplifier 23a increases the offset voltage in order to shift the direct current level of the split signal from splitter 22, and supplies it as a modulated signal to the number 1 frequency modulator 3a. On the other side, the inverse amplifier 23b inverts the polarity of the split signal from splitter 22, increases the offset voltage to shift the direct current level, and supplies it as a modulated signal to the number 2 frequency modulator 3b. The number 1 and number 2 frequency modulators 3a, 3b each frequency modulate the carrier waves that were input from the number 1 and number 2 carrier wave generators 1a, 1b using the modulated signals that had their direct current levels shifted by the amplifier 23a and the inverse amplifier 23b. The resulting frequency modulated signal is then input to the mixer 24. The mixer 24 mixes these two frequency modulated signals, and supplies them to a high pass filter 25 which cuts off the frequency at, for instance, 20 kHz. The high pass filter 25 discards the component of the mixed signal output from the mixer 24 that is below 20 kHz, and supplies the result to the compensating filter 26.

Incidentally, the ultrasonic wave generator 5 has a mechanical resonating frequency in the range of, for instance, 40 kHz, and the characteristics of that frequency are not even. Therefore, the compensating filter 26 regulates a designated component, for instance the component in the range of 40 kHz, of the frequency modulated signal from the high pass filter 25, and supplies the resonance frequency component controlled frequency modulated signal to the ultrasonic wave generator 5 via the amplifier 27. The ultrasonic wave generator 5 contains for instance, at least one ultrasonic wave generating element, and is driven by the frequency modulated signal that was amplified by amplifier 27, to

broadcast ultrasonic waves with high directivity based on the frequency modulated signal in the direction that the ultrasonic wave generator 5 is pointed.

Now the principle behind why the sound from the speaker devices can be heard will be simply explained.

The signal 0 (t) that is the mixture of the two frequency modulated signals is expressed by Equation 4 below.

Equation 4

The secondary distortions of this signal 0 (t) can be expressed using Equation 5 below.

Equation 5

Items 1 through 3 of Equation 5 are the lateral range waves centered upon the direct current, 2 ω_c, 2 ω_c', and ($\omega_c + \omega_c'$). Item 4 represents the lateral range waves centered on ($\omega_c - \omega_c'$), and these lateral range waves exist in the audible range, and therefore can be heard by humans. It follows that when Item 4 is equal to the source audio signal s (t), or in other words, when Equation 6 is met, the audio signal can be heard.

Equation 6

Where $|s(t)| \leq 1$, $\Delta\omega_c = \omega_c - \omega_c'$, and $\Delta\theta = \theta_c - \theta_c'$, and $\Delta k = k - k'$. In order to simplify Equation 6, s (t) which has been normalized by A_cB_c shall hereafter be referred to as s (t).

When Equation 6 is solved for h (t), the following Equation 7 is obtained.

Equation 7

When the carrier waves are frequency modulated using a signal h (t) that follows Equation 7, in

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other words, when the audio signal from the audio signal source 2, after processing by an inverse cosine function, is given a direct current offset, and the resultant signal is split, and this split signal is used to frequency modulate the carrier waves, a sound corresponding to the original audio signal can be heard.

Incidentally, when s (t) is sufficiently small, by using serial development, the $\cos^{-1}$ s (t) portion of Equation 7 can approach $\pi / 2 - s$ (t), and the signal h (t) can be expressed using Equation 8.

Equation 8

Also, the speaker device performs the signal processing that relates to Equation 8 in the splitter 22, the amplifier 23a, and the inverse amplifier 23b.

Next, other specific examples of speaker devices that relate to this invention will be explained using Figure 7 as a reference.

As shown in Figure 7, the speaker device, along with having only one of the carrier wave generators 1a, 1b as shown in Figure 6, has added amplitude modulators 28a, 28b placed after the frequency modulators 3a, 3b, and also has a preprocessing circuit 30 added before the amplitude modulators.

These added amplitude modulators 28a, 28b, uses the audio signal prepared as explained below by the preprocessing circuit 30 as the modulator signal, and the frequency modulated signal from the frequency modulators 3a, 3b as the carrier waves, and modulates the carrier waves using the modulator signal, and the resulting amplitude modulated signal is supplied to the mixer 24.

Here the principle behind why sound can be heard from this speaker will be simply explained. When the conditions $A_c = B_c = A_c' / 2$, $\Delta\omega_c = \omega_c - \omega_c' = 0$, $\Delta\theta = \theta_c - \theta_c' = 0$, and $k' = 0$ are added to Equation 4, it can be converted to Equation 9 as shown below.

Equation 9

Incidentally, when η (t) is the modulator signal for the amplitude modulation, it can be expressed as shown below in Equation 10.

Equation 10

When Equation 11 is met, the same signal as Equation 9 can be obtained by Equation 10.

Equation 11

It follows that for this speaker device, if for instance, the preprocessing circuit contains a digital signal processor (DSP) and a memory that contains the data and instructions to drive the DSP, and if the DSP, as shown in Figure 9, contains an inverse cosine function operator 31 which seeks the inverse cosine value of the audio signal, a multiplier 32 which takes 1/2 of the output from the inverse cosine function operator 31, and a cosine function operator 33 that seeks the cosine value of the output of the multiplier 32, then the signal processing corresponding to Equation 11 will be performed. In other words, the inverse cosine function operator 31 performs the inverse cosine function on the audio signal from the audio signal source 2, the multiplier 32 multiplies the obtained results by 1/2, and the cosine function operator 33 seeks the cosine value of the output from the multiplier 32.

Incidentally, Item 2 of Equation 11 can be converted as shown by Equation 12 below.

Equation 12

It follows that the preprocessing circuit 30, as shown for example in Figure 10, can be designed with a direct current offset adder 34 which gives the audio signal a direct current offset, a multiplier 35 which multiplies the output from the direct current offset adder 34 by 1/2, and a square root operator 36 that seeks the square root of the output from the multiplier 35. By constructing the preprocessing circuit 30 in this manner, the DSP does not need to perform the operation that seeks the cosine function or the inverse cosine function, and only one square root operation needs to be performed so the processing time and memory capacity may be reduced. Also, in the case where these operation processes are performed by hardware, the circuit scale may be reduced.

Also, the operation to multiply by 1/2 only affects a change on the amplitude of the modulated output, so it can be eliminated. In other words, the preprocessing circuit 30 may be designed as shown for example in Figure 11 with a direct current offset adder 34 which gives the audio signal a direct current offset and a square root operator 36 that seeks the square root of the output from the direct current offset adder 34. By constructing the preprocessing circuit 30 in this manner, the DSP does not need to perform the operation that seeks the cosine function or the inverse cosine function, and only one square root operation needs to be performed so the processing time and memory capacity may be reduced.

Also, incidentally, in the actual speaker devices mentioned above, the carrier waves are frequency modulated using the audio signal, and the obtained frequency modulated signal is used to drive the ultrasonic wave generator 5, which as mentioned above, contains multiple piezoelectric elements. It is acceptable to place a compensating filter 26 as a step prior to each piezoelectric element in order to obtain the desired frequency characteristics and directivity. Also, it would be acceptable to include an amplifier 4

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as shown in Figure 1 and Figure 2, or amplifier 27 as shown in Figure 6 or Figure 7, in order to obtain the desired frequency characteristics and directivity. Also, it would be acceptable to perform a compensating process at the audio signal level in order to achieve the desired frequency characteristics.

Also, it is acceptable to take two of the speaker devices mentioned above, and supply a different audio signal to each individual speaker device, and at the same time put a filter with different frequency characteristics and phase characteristics before the piezoelectric elements of each speaker device. In this case, sounds with different directivity characteristics can be emitted from the same position, so that depending on the position of the listener, the sound that is heard will be different.

The speaker devices of this invention have extremely high directivity characteristics, so audio information can be delivered towards a specific position.

Therefore, audio signal transmitter devices with a privacy function can be structured without transmission wires, etc.

This audio transmission device, as shown in Figure 8 for example, consists of an audio signal source 41 that outputs the audio signal, a preprocessor 42 which splits the audio signal and uses it to frequency modulate the carrier waves, an ultrasonic wave generator 44 which is driven by the frequency modulated signal from the preprocessor 42, an audible range microphone 45, and a post-processor 46 which performs the inverse cosine function on the signal from the microphone 45.

The preprocessor 42 consists of a compensating filter 26 and an amplifier 21 that was used in the previously mentioned speaker device example shown in Figure 6, and drives the ultrasonic wave generator 44 via the amplifier 43 using the frequency modulated signal that was obtained by frequency modulating the carrier signal using the audio signal. It follows that the portion of the sound waves emitted from the ultrasonic wave generator 44 that has a differential frequency distortion, and therefore can be heard by humans can be expressed as Item 4 of the previously mentioned Equation 5, or in other words, as shown by Equation 13.

Equation 13

The microphone 45 detects sounds in the audible range, and therefore outputs the signal y (t) as shown in Equation 13. The post-processor 46 processes the signal corresponding to Equation 14 and restores the original audio signal h (t).

Equation 14

Therefore, when the user uses headphones, for example, and the signal from the post-processor 46 is played, sound that corresponds to the original signal can be heard. Incidentally, if a third party is

between the ultrasonic wave generator 44 and the microphone 45, the distortion will be large, and the sound will be indistinguishable. Also, a third party not where the ultrasonic wave generator 44 is pointed, or in other words, outside of the directivity range, cannot hear the sound. Therefore, by using this audio signal transmitter device, the contents of the audio signal cannot be intercepted by a third party.

Now, specific examples of compensation processing to achieve the previously mentioned desired frequency characteristics will be explained.

In the speaker devices in the example shown in Figure 7, after frequency modulation by the audio signal, the signal is amplitude modulated using the output from the preprocessor circuit 30. Therefore, if the modulation level is the same size, the output from the frequency modulators 3a, 3b (hereafter referred to simply as the modulator output) or in other words h (t) can be expressed by Equation 15 below, and the output from the amplitude modulators 28a, 28b or in other words g (t) can be expressed using Equation 16 below.

Equation 15

Equation 16

Now if the modulation levels in Equation 15 are equal, then the sum of the modulation levels is 0, and the frequency modulation component in the cosine function disappears, and the whole Equation 16 represents only the amplitude modulation.

If a Fourier transformation is performed on h (t) or in other words the output from the preprocessor circuit 30, the result is H (ω) as shown in Equation 17, and the modulator output g (t), as shown in Equation 16, when using H (ω), transforms to Equation 18.

Equation 17

Equation 18

Now, the second degree distortion g_2 (t) of the signal g (t) and its Fourier transformation are shown in Equation 19 and Equation 20 below.

Equation 19

Equation 20

Now, as shown in Equation 21 and Equation 22 below, if the range of H (ω) is limited by the angular frequency ω_s, and mainly distributed in the audio range, and the modulation center frequency is over twice ω_s in the ultrasonic wave range, then,

Equation 21

Equation 22

Concerning the 4 items in Equation 20,

Equation 23

The conditions for Equation 23 are shown below.

Also, the subject used here is the second degree distortion of the audio range component (differential frequency). Therefore in Equation 20, the first two items that are the components distributed in the ultrasonic range ($\pm 2\,\omega_c - 2\,\omega_s \leq \pm 2\,\omega_c + 2\,\omega_s$) may be ignored, and emphasis put only on the last 2 items that are the components distributed in the proximity of the audible range ($-2\,\omega_s \leq \omega \leq +2\,\omega_s$), and Equation 24 shown below is obtained.

Equation 24

Ideally, the output from the amplitude modulators 28a, 28b or in other words g (t), with its original characteristics would be emitted from the ultrasonic wave generator 5, and the differential frequency component of the second degree distortions that occur in the air would be identical to the audio signal that they were based upon. However, because of the characteristics of the ultrasonic wave generators 5, and the previous amplifier 27, sound that corresponds to the signal g (t) does not occur. Here, the characteristic of the speaker to modify the characteristics of the signal g (t) shall be called a (t).

As shown in Equation 25 and Equation 26, the speaker output, or in other words the ultrasonic wave generator output, or in other words x (t), can be expressed as a convolution of the signal g (t) and the speaker characteristic a (t).

Equation 25

Equation 26

In Equation 25, the * refers to the convolution operation.

In order to eliminate the effects of the speaker characteristics a (t) on the speaker output X (ω) in Equation 26, a filter must be added before the speaker that has the reverse characteristics of the speaker characteristics a (t) at least over the range that the modulator output $\acute{G}$ (ω) is distributed. Specifically, as shown in Figure 12 for example, a compensating filter 126 that has the reverse characteristics of the ultrasonic wave generator 5 is added to the output of the amplitude modulator 28, causing the input to the ultrasonic wave generator to appear as shown below in Equation 27.

Equation 27

Now, at this point, specific examples of compensation processing at the audio signal level to obtain the desired frequency characteristics will be explained.

Similar to the development of G_2 (ω) as shown in Equation 20 above, while holding the conditions $|\omega| \leq 2\,\omega_a$ etc., the audio range component of the second degree distortion x_2 (t) can be obtained as shown in Equation 29 below.

Equation 28

Equation 29

Simply stating the development flow of Equation 28, the effects of the modulation using the signal H (k) centered around ω_c are replaced with the equation for the speaker characteristics A (k). In Equation 29, the speaker characteristics A (k - ω_c), A (k + ω_c) correlate to the speaker characteristics that have the modulation effect.

As shown in Figure 14 (C), the speaker characteristic has a power characteristic that is not flat, but has a peak in the modulated angular frequency $\pm \omega_c$. Moreover, the peak has different curves on both sides. The characteristic shown in Figure 14 (C) is a typical simplified pattern of the characteristics of an ultrasonic wave piezoelectric element, but in the case where the power is displayed digitally, the characteristic has an approximately straight line slope.

In order to compensate this type of asymmetric speaker characteristic in the audio range, or in other words, in the output of the preprocessor circuit 30 shown for example in Figure 13, it is necessary to simultaneously compensate for two types of characteristics as shown in Figure 14 (D). In order to simply accomplish this the following methods can be considered.

- a piezoelectric element which has a power curve that is comparable to the modulator frequency (frequency of the carrier wave) on both sides.
- during or after modulation processing, compensate to assure symmetry.

Compensating during or after modulation processing to assure symmetry is represented by Equation 30 below, and so Equation 31 shown below is established.

Equation 30

Equation 31

Also, previously mentioned Equation 29 that shows the second degree distortion of the speaker output, can be converted to Equation 32, and the speaker characteristic A (k) can be processed along with the amplitude modulator 28 input signal H (k).

Equation 32

By doing this, similar to the distribution in the audio range, across the $| k | \leq \omega_s$ of the converted speaker characteristic $A (K + \omega_c)$, the inverse characteristic $A^{-1} (K + \omega_c)$ can be multiplied by $H (\omega)$ and a new $H_a (\omega)$ obtained from Equation 32, is input into the amplitude modulator 28. Specifically, as shown by Figure 13 for example, a compensating filter 226 for the previously mentioned inverse characteristic $A^{-1} (K + \omega_c)$ is placed between the preprocessor circuit 30 and the amplitude modulator 28.

Next, several examples of uses of the speaker devices associated with the previously mentioned invention will be explained.

Figure 15 shows an ultrasonic wave generator 61, which is assembled from multiple piezoelectric elements 50, attached to the rear view mirror 60 in the interior of an automobile. This time, the ultrasonic wave generator 61 uses multiple piezoelectric elements 50, which are arranged in two rows along the bottom edge of the rear view mirror 60.

The rear view mirror 60 of an automobile is usually directed towards the driver 62, so the ultrasonic wave generator 61 can be pointed at the driver 62, and the ultrasonic waves emitted from the ultrasonic wave generator 61 can be concentrated towards the driver 62, so only the driver 62 will hear the sounds. Therefore, it follows that the speakers can be designed so that only the driver 62 is able to hear the necessary audio information.

Also, because the ultrasonic waves emitted from the ultrasonic wave generator 61 have high directivity, if a microphone 63 is attached to a part of the rear view mirror 60, an input output device for a hands free type communication device can be made. In this case, because the ultrasonic waves emitted from the ultrasonic wave generator 61 have extremely high directivity, even if the microphone 63 is placed in close proximity to the ultrasonic wave generator 61 the ultrasonic waves emitted from the ultrasonic wave generator 61 are not input to the microphone 63, and therefore howling and other problems are eliminated. Also, because the ultrasonic waves emitted from the ultrasonic wave generator 61 are

concentrated on the driver 62, it can prevent a rider 64 in the vehicle from listening to the audio information, and so at least the receiving portion of the audio information can be kept private.

Also, if several individual groups of the piezoelectric elements 50 that make up the ultrasonic wave generator 61 are combined, and a filter is added as a preliminary step in front of each group of piezoelectric elements 50 so that the frequency characteristics and phase characteristics of each group of piezoelectric elements 50 is different, then the characteristic direction of the wave surface of the ultrasonic waves emitted by each group of piezoelectric elements 50 can be set, and the driver 62 and the passenger 64 will each be able to listen to different sounds or music.

Also, Figure 16 shows an example of the speaker devices of this invention used for a conference system. This conference system is made of several units consisting of a microphone 73 and an ultrasonic wave generator which is made of several piezoelectric elements 50, and the units are arranged evenly spaced on a conference table 71. By arranging several of these ultrasonic wave generators 72, the audio information emitted from each of the ultrasonic wave generators 72 can be concentrated on the individual user 74 corresponding to that ultrasonic wave generator 72 and each listener 74 will be supplied different information. For instance, in the case where the native language of the listeners is different, information in different languages can be supplied to each listener 74.

Also, Figure 17 shows an example of a video telephone that uses the speaker devices of this invention. This video telephone device has a microphone 83 and an ultrasonic wave generator 82 composed of several piezoelectric elements 50 arranged on the upper portion of the receiver device 81. Because the ultrasonic waves emitted from the ultrasonic wave generator 82 have extremely high directivity, the ultrasonic wave generator 82 can be pointed towards the user 84, and even though the microphone 83 is in close proximity to the ultrasonic wave generator 82, the ultrasonic waves emitted from the ultrasonic wave generator 82 are not input into the microphone 83, and so howling and other such problems are eliminated, and a hands free type vocal input output device can be made.

Also, Figure 18 shows an example of the speaker devices associated with this invention combined with the sound system of an airplane, bus, or other public transportation vehicle. The ultrasonic wave generator 91 of the speaker devices used for this sound system are made by combining multiple piezoelectric elements 50, and are arranged pointed towards the listener 93 sitting in each individual seat 92. With the ultrasonic wave generators 91 arranged in this manner, audio information can be provided to the desired listener 93 without the use of privacy headphones etc.

Next, Figure 19 shows an example of the speaker devices associated with this invention used in a projection type video projector. This video projector has several groups of ultrasonic wave generators 102 each containing several piezoelectric elements 50 built into the main body 101 of the projector. This time the various ultrasonic wave generators 102 that are built in the projector main body 101 are pointed

towards the screen or projection surface 103, or other wall surfaces. When each ultrasonic wave generator 102 emits ultrasonic waves towards the screen surface 103, or other walls, the sound phenomenon for the listener can be oriented to the reflection point of the ultrasonic waves emitted from each ultrasonic wave generator 102.

Therefore, by causing the various ultrasonic wave generators to emit ultrasonic waves corresponding to a multi-channel sound source consisting of a right channel, a left channel, a center channel, a right surround channel, and a left surround channel, the listener 104 can be provided an acoustic reproduction of a multiple channel sound source.

Next, Figure 20 shows an example of the speaker devices associated with this invention used in an audio visual device which uses a thin video display device 110 like a liquid crystal display device or a plasma display, etc. The speaker devices used for this audio visual device use an ultrasonic wave generator 114 which consists of multiple piezoelectric elements 50 installed in the light reflection plate 113 of lighting equipment 112, which includes a light fixture 111, and is suspended down from the ceiling. The various piezoelectric elements 50, which make up the ultrasonic wave generators 114 are each attached to the light reflection plate 113 in a designated direction. This time, if the various piezoelectric elements 50 which make up the ultrasonic wave generators 114 are combined into various groups, and a filter is set as a previous step to each group of piezoelectric elements 50, each group of piezoelectric elements 50 can have different frequency characteristics and phase characteristics, and therefore, each group of piezoelectric elements 50 can have their directivity pointed in directions other than the front.

Therefore, by changing the direction of the ultrasonic waves emitted by the various piezoelectric elements 50, the ultrasonic wave generator 114 that is made of multiple piezoelectric elements 50 can emit ultrasonic waves corresponding to a multi-channel sound source consisting of a right channel, a left channel, a center channel, a right surround channel, and a left surround channel, and the listener 115 can be provided an acoustic reproduction of a multiple channel sound source.

Also, Figure 21 shows an example of the speakers associated with this invention used in a pointer device 121 for an overhead projector. This pointer device 121 emits a laser light 122, and uses the laser light 122 to highlight a specific point on a display surface 123, and it has an ultrasonic wave generator 124 consisting of multiple piezoelectric elements 50 arranged on the side of the pointer device that emits the laser light. Therefore, by combining the ultrasonic wave generator 124 with the pointer device 121, the presenter 125 can reflect ultrasonic waves off of the position 122a that the laser light 122 is pointed at, thus creating a sound phenomenon oriented at the point position 122a, providing effective information that combines both laser light highlight and sound.

Next, Figure 22 is an example of the speaker devices of this invention used in a player device that

reproduces the multilingual information recorded on an information recording medium. This player device 131 has a main body 133 which contains the image receiver 132, and also has an ultrasonic wave generator 134 which consists of multiple piezoelectric elements 50 arranged along the top edge. This ultrasonic wave generator 134 is composed of two groups 134a, 134b of multiple piezoelectric elements 50, and by driving the two groups with modulated signals modulated using different audio signals corresponding to different languages for instance, multiple listeners 135 can listen independently to the language of their choice.

Also, Figure 23 is an example of the speaker devices of this invention used in a dual screen television video receiver 141. This television video receiver 141 has ultrasonic wave generators 144 that contain multiple piezoelectric elements 50, arranged along the top edge of the main body 142 of the video receiver. The multiple piezoelectric elements 50 that make up the ultrasonic wave generators 144 are divided into two groups 144a, 144b which correspond to each of the video receiver screens 141a, 141b. By driving each group of ultrasonic wave generators 144a, 144b using the modulated signal that was modulated by the audio signal that corresponds to each video receiver screen 141a, 141b, the vocal sounds that correspond to the image displayed on each video receiver screen 141a, 141b can be provided to each listener 145 without any reciprocal interaction effects.

Also, Figure 24 is an example of the speaker devices of this invention used in a television video receiver 151. This television video receiver 151 has ultrasonic wave generators 154 that contain multiple piezoelectric elements 50, arranged along the top edge of the main body 152 of the video receiver. Here, the directivity of each of the piezoelectric elements 50 that make up the ultrasonic wave generators 154 is pointed at the left and right ear of the listener 155, so that when each piezoelectric element 50 is driven by the modulated signal that was modulated using the audio signal from a binaural recording, a three-dimensional acoustic effect can be heard without using headphones.

Also, when the directivity of the piezoelectric elements 50 of the speaker devices of the player device 131 or the television video receiver device 141 of the previously mentioned Figure 22 or Figure 23 are pointed at the left and right ear of the listener, and each piezoelectric element 50 is driven by the modulated signal that was modulated using the audio signal from a binaural recording, a three-dimensional acoustic effect can be heard without using headphones.

Also, Figure 25 is an example of the speakers associated with this invention used in an art or science museum, where ultrasonic wave generators 162 containing multiple piezoelectric elements 50 are arranged in the ceiling above an exhibit 161. This time, the ultrasonic wave generators 162 have their directivity pointed towards the front of the exhibit 161, so that only the patron 163 that is viewing that particular exhibit will be able to hear the reproduced sound, and the quite peaceful environment of the exhibition room can be maintained.

Also, the speaker devices shown in Figure 26 use an ultrasonic wave generator 171 consisting of multiple piezoelectric elements 50 to emit ultrasonic waves in the direction of two vibrating plates 172, 173 that are positioned some distance away, and reproduced sounds in the audible range can be heard by reflecting off of the vibrating plates 172, 173. The vibrating plates 172, 173 are attached around the edges using a film etc. that has a designated resilience.

Using this construction, the vibrating plates 172, 173 can be located freely, without the need to attach a power source or a drive system.

By designing a room using the vibrating plates 172, 173, it would be possible to make use of a room interior structure.

Also, Figure 27 is an example of the speaker devices of this invention used for a television receiver 181, that follows the listener 182, and can adjust the directivity to the position of the listener 182. This television receiver 181 has an ultrasonic wave generator 184 consisting of multiple piezoelectric elements 50 arranged along the top edge of the receiver main body 183, and a position detector device 185 that can detect the position of the listener 182 is arranged on the top of edge of the ultrasonic wave generator 184. By adjusting the directivity of the ultrasonic wave generators 184 based on the detection output from the position detector device 185, the ultrasonic waves emitted can be adjusted to the position of the listener 182. This time, the multiple piezoelectric elements 50 are aligned in two rows along the top edge of the video receiver main body 183.

Also, Figure 28 shows another example of the speaker devices of this invention used with a television video receiver 191 that has placed on the top of the main body 193 of the video receiver device a video tracking device 192 with a rotating or moveable mechanism, that can recognize a designated object using video processing, and can follow that device. An ultrasonic wave generator 194 consisting of multiple piezoelectric elements 50 is attached to a part of this video tracking mechanism 192.

The multiple piezoelectric elements 50 that make up the ultrasonic wave generator 194 are arranged with a group on each side of the video tracking device 192.

By attaching the ultrasonic wave generator 194 to the video tracking mechanism 192 so that they move or rotate together while tracking a designated object, it is possible to provide the audio information only to the listener 195.

Possibility of Industrial Uses

The speaker devices of this invention have a means to frequency modulate the audio signal output from a sound source to a signal with a frequency at least higher than the audible range, and uses the frequency modulated signal from that device to drive ultrasonic wave generating elements, and the

ultrasonic wave generating elements emit ultrasonic waves to the air, or reflect them off of a vibrating plate to obtain audible sound which has a very high directivity, and can be used to freely set the sound phenomenon to a desired position.

Because audio signal transmitter receiver devices using these speaker devices can obtain extremely high directivity, audio signals with satisfactory privacy characteristics can be transmitted and received.

Extent of Claims

1. A speaker device that contains a modulator device that frequency modulates an audio signal to a frequency range at least higher than the audible range, and that uses the output signal from the above modulator device to drive at least one ultrasonic wave generating element.
2. The speaker device of Extent of Claims Item 1 with a modulator device that modulates the above audio signal to a number 1 frequency modulated signal based on a number 1 frequency, and also modulates the above audio signal to a number 2 frequency modulated signal based on a number 2 signal that is different than the number 1 signal mentioned above.
3. The speaker device of Extent of Claims Item 1 which contains multiple ultrasonic wave generating elements, where some of the above mentioned ultrasonic wave generating elements are provided the number 1 signal mentioned above, while the rest of the ultrasonic wave generating elements are provided the number 2 signal mentioned above.
4. The speaker device of Extent of Claims Item 1 which contains a splitter to split the above mentioned audio signal, and also contains a modulator device with a number 1 and a number 2 modulator part, where one of the parts of the modulator is provided an output signal from the above mentioned splitter, while the other part of the modulator is provided a signal with the reversed polarity to the output signal from the splitter.
5. The speaker device of Extent of Claims Item 4 which also contains, a number 1 circuit that provides to either the number 1 or number 2 modulator part described above a signal which has the direct current level shifted from the output signal from the above mentioned splitter, and also contains a number 2 circuit that provides to the other modulator part mentioned above a signal which has the direct current level shifted and the polarity reversed from the output signal from the above mentioned splitter.
6. The speaker device of Extent of Claims Item 5 which also contains a preprocessing device which preprocesses the audio signal, a number 1 amplitude modulator which amplitude modulates the output signal from the above mentioned preprocessor using the output signal from the above mentioned number 1 modulator part of the modulator device as carrier waves, and a number 2

amplitude modulator which amplitude modulates the output signal from the above mentioned preprocessor using the output signal from the above mentioned number 2 modulator part of the modulator device as carrier waves.

7. The speaker device of Extent of Claims Item 6 which has a preprocessor which contains a number 1 signal processor which seeks the reversed cosine value of the above mentioned audio signal, a number 2 signal processor which multiplies the output from the number 1 signal processor by 1/2, and a number 3 signal processor which seeks the cosine of the output from the number 2 signal processor.
8. The speaker device of Extent of Claims Item 6 has the above mentioned preprocessor which has a number 1 signal processor part which gives the audio signal a direct current offset, and a number 3 signal processor part which seeks the cosine of the output from the number 2 signal processor mentioned above.
9. The speaker device of Extent of Claims Item 6 contains the above mentioned preprocessor which has a number 1 signal processor which gives a direct current offset to the audio signal mentioned above, and a number 2 signal processor which seeks the square root of the output of the above mentioned number 1 signal processor.
10. The speaker device of Extent of Claims Item 6 which contains a compensating filter which is placed between the above mentioned modulator device, and the above mentioned ultrasonic wave generating elements.
11. The speaker device of Extent of Claims Item 10 which has the above mentioned compensating filter which regulates from the output signal that is output from the above mentioned modulator device the component that has the resonant frequency of the above mentioned ultrasonic wave generating elements.
12. The speaker device of Extent of Claims Item 10 which has the above mentioned compensating filter with the inverse characteristics to the speaker characteristics at least over the frequency range that the output from the number 1 and number 2 amplitude modulators is distributed.
13. The speaker device of Extent of Claims Item 1 which also has a high pass filter located between the above mentioned modulator devise and the above mentioned ultrasonic wave generating element.
14. The speaker device of Extent of Claims Item 13 which also has a compensating filter placed between the above mentioned modulator device, and the above mentioned high pass filter.
15. The speaker device of Extent of Claims Item 14 which has the above mentioned compensating filter which regulates the component of the output signal that is output from the modulator device that is at the resonant frequency of the above mentioned ultrasonic wave generating elements.
16. The speaker device which contains a modulator device that frequency modulates the audio signal at

least to a frequency range that is higher than the audible frequency range, and contains at least one ultrasonic wave generating element that is driven by the output signal from the above mentioned modulator device, and contains a compensating device that is placed between the above mentioned modulator device and the above mentioned ultrasonic wave generating element.

17. The speaker device of Extent of Claims Item 16 which contains the above mentioned compensating device which is made using a filter which regulates the component of the output signal that is output from the above mentioned modulator device that is at the resonant frequency of the above mentioned ultrasonic wave generating elements.

18. The speaker device which contains:

a modulator device that has a number 1 and a number 2 part, and has the audio signal provided to either the above mentioned part 1 or part 2 of the modulator device, while the other modulator part is provided a signal that inverse to the audio signal, and which frequency modulates the above mentioned audio signal to a signal with a frequency range at least higher than the audible frequency range,

an ultrasonic wave generator that is driven by the output signal from the above mentioned modulator device,

an ultrasonic wave generator as mentioned above, which has a part 1 generator part which is composed of multiple ultrasonic wave generating elements which are driven based on the output signal from the above mentioned part 1 modulator part, and a part 2 generator part which is composed of multiple ultrasonic wave generating elements which are driven based on the output signal from the above mentioned part 2 modulator part

19. The speaker device of Extent of Claims Item 18 which also has a high pass filter located between the above mentioned modulator devise and the above mentioned ultrasonic wave generating element.

20. The speaker device of Extent of Claims Item 19 which also has a inverse circuit which inverts the amplitude of the above mentioned audio signal.

21. The speaker device of Extent of Claims Item 18 which also has the above mentioned number 1 and number 2 modulator parts which frequency modulate based on the same carrier wave.

22. The speaker device of Extent of Claims Item 18 which also has the above mentioned ultrasonic wave generating elements which are made of piezoelectric elements.

23. The audio signal transmitter receiver device which has:

a modulator device that frequency modulates the carrier wave using the split signal,

an ultrasonic wave generator that is driven based on the output signals from the above mentioned modulator device,

a microphone that detects the sound waves that are output from the above mentioned ultrasonic

wave generator;

and an operator which performs the reverse cosine function on the output signal from the above mentioned microphone.

24. The audio signal transmitter receiver device of Extent of Claims Item 23 which has the previously mentioned microphone which detects the sound waves in the audible frequency range that are output from the above mentioned ultrasonic wave generator.
25. The drive method of the speaker device which is composed of at least one ultrasonic wave generating element, which first frequency modulates the audio signal that was input to a signal with a frequency range that is at least higher than the audible frequency range, and then drives the above mentioned ultrasonic wave generating elements using the above mentioned frequency modulated signal.
26. The drive method of the speaker device of Extent of Claims Item 25 which modulates the above audio signal to a number 1 frequency modulated signal based on a number 1 frequency, and also modulates the above audio signal to a number 2 frequency modulated signal based on a number 2 signal that is different than the number 1 signal mentioned above.
27. The drive method of the speaker device of Extent of Claims Item 26 that contains multiple ultrasonic wave generating elements, and provides to a portion of the above mentioned ultrasonic wave generating elements the above mentioned number 1 signal, and provides to the rest of the above mentioned ultrasonic wave generating elements the above mentioned number 2 signal.
28. The drive method of the speaker device of Extent of Claims Item 25 which splits the previously mentioned audio signal, and then drives the previously mentioned ultrasonic wave generating elements based on a number 1 signal that was frequency modulated using the signal from the above mentioned splitter, and a number 2 signal that was frequency modulated using a signal with the reverse polarity to the signal from the above mentioned splitter.
29. The drive method of the speaker device of Extent of Claims Item 25 which splits the above mentioned audio signal, and then drives the above mentioned ultrasonic wave generating elements based on a number 1 signal that has been frequency modulated using a signal which has the direct current shifted from the signal that came from the above mentioned splitter, and a number 2 signal which has been frequency modulated using a signal which has the direct current level shifted, and the polarity inverted from the signal that came from the above mentioned splitter.
30. The drive method of the speaker device of Extent of Claims Item 25 which drives the above mentioned ultrasonic wave generating elements based on a number 1 amplitude modulated signal which was amplitude modulated from the signal which was preprocessed from the above mentioned audio signal using the above mentioned number 1 signal as the carrier waves, and a number 2 amplitude modulated signal which was amplitude modulated from the signal which was preprocessed

from the above mentioned audio signal using the above mentioned number 2 signal as the carrier waves.

31. The drive method of the speaker device of Extent of Claims Item 30 which performs preprocessing on the above mentioned audio signal by finding the inverse cosine of the above mentioned audio signal, and multiplying the value of the resultant inverse cosine value by 1/2, and then calculating the cosine of the resulting 1/2 of the inverse cosine value.

32. The drive method of the speaker device of Extent of Claims Item 30 which performs preprocessing on the above mentioned audio signal by giving the above mentioned audio signal a direct current offset, and multiplying the value of the resultant direct current offset output by 1/2, and then taking the cosine of the resulting 1/2 of the inverse cosine value. [The translator believes that this should read ...and then taking the cosine of the resulting 1/2 of the direct current offset output.]

33. The drive method of the speaker device of Extent of Claims Item 30 which performs preprocessing on the above mentioned audio signal by giving the above mentioned audio signal a direct current offset, and then finding the square root of the output that was given the direct current offset.

34. The drive method of the speaker device of Extent of Claims Item 30 which regulates the component of the previously mentioned number 1 and number 2 amplitude modulated signals which has the resonance frequency of the above mentioned ultrasonic wave generating elements.

35. The drive method of the speaker device of Extent of Claims Item 30 which compensates the above mentioned number 1 and number 2 amplitude modulated signals using a filter which has the inverse characteristics as the above mentioned speaker device at least through the frequency range that the above mentioned number 1 and number 2 amplitude modulated signals are distributed.

36. The drive method of the speaker device of Extent of Claims Item 25 which also feeds the above mentioned frequency modulated signal to the above mentioned ultrasonic wave generating elements via a high pass filter.

37. The drive method of the speaker device of Extent of Claims Item 36 which also regulates the component of the previously mentioned frequency modulated signal which has the resonance frequency of the above mentioned ultrasonic wave generating elements.

Translation of Japanese in Figures

1. Audio signal source
2. Figure 1

3. Audio signal source
4. Figure 2
5. Figure 3
6. Figure 4
7. Sound pressure level
8. Figure 5
9. Audio signal source
10. Offset
11. Offset
12. Compensating filter
13. Figure 6
14. Audio signal source
15. Offset
16. Offset
17. Preprocessor
18. Compensating filter
19. Figure 7
20. Preprocessor
21. Post processor
22. Figure 8
23. Reverse cosine function operator
24. Cosine function operator
25. Figure 9
26. Direct current offset adder
27. Square root operator
28. Figure 10
29. Direct current offset adder
30. Square root operator
31. Figure 11
32. Preprocessor
33. Modulated angular frequency
34. Modulator
35. Compensating filter
36. Figure 12

37. Preprocessor
38. Compensating filter
39. Modulated angular frequency
40. Modulator
41. Figure 13
42. Modulator input (Preprocessor output)
43. Modulator output
44. Speaker characteristic
45. Speaker characteristic in the audio band in the area where $k = 0$
46. Figure 14